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Demonstration Plan For Real Time Receiving and Processing of Flight Data From The Space Transportation System

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Abstract

This report presents a detailed demonstration test plan for receiving and processing data from experiments being conducted on the Space Transportation System near real time at the NASA Langley Research Center (LaRC). This task can readily be achieved using the Orbital Acceleration Research Experiment (OARE). The Space Shuttle data flow is described including both the payload and the mission data. A description is presented of the OARE instrument which is used to measure low frequency Space Shuttle accelerations in nano-gs. Procedures are shown for obtaining the required mission data and OARE payload data at LaRC. The demonstration test plan schedule and costs are presented. It is recommended that both the OARE data and the pertinent Space Shuttle mission data be received at LaRC over the NASA Communication System (NASCOM) on a near real time basis.

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Introduction

The purpose of this task is to determine an approach for performing a demonstration to receive, process, and analyze data from experiments being conducted on the Space Transportation System near real time at NASA Langley Research Center (LaRC). This task can readily be achieved by using the Orbital Acceleration Research Experiment (OARE). Therefore, from this point on this report will describe how this task can be achieved by describing the procedures that could be used with the OARE instrument. Currently the OARE data is received at the JSC ground station and recorded on tape in pulse code modulated (PCM) format and is not processed on a real time basis. The OARE PCM data tape is then converted at NASA Johnson Space Center (JSC) to a computer compatible tape and mailed to the researchers at LaRC for post mission processing and analysis.

With the current interest in defining the microgravity environment of the Space Shuttle, it is believed that it is more efficient to receive, process, and analyze the OARE data at LaRC directly and without conversion to computer compatible tape. To determine the feasibility of receiving OARE data at LaRC in near real time, demonstration tests are required. A separate program is underway to develop procedures and software for processing and analyzing the OARE data at LaRC.

Analysis of the OARE data involves not only the OARE instrument data, but also the Space Shuttle mission data. The OARE data is transmitted as part of the payload data stream, whereas the mission data is received and processed at JSC and then transmitted to Goddard Space Flight Center (GSFC) where they are further processed and transmitted to various user centers. Therefore, each data set must be received and processed separately. This report presents a detailed plan for receiving, processing, and analyzing the OARE data including the required hardware and software systems. A proposed demonstration test schedule is presented to develop the capability at LaRC to receive, process, and analyze the OARE data near real time. These procedures can then be applied to any experiment being conducted in space.

OARE Instrument

The OARE instrument is a triaxial electrostatic accelerometer package with on-orbit calibration capabilities and has a sensitivity of less than three (3) nano-gs on each axis. Figure 1 shows the instrument package and Figure 2 shows the package installed in the floor of the Space Shuttle cargo bay. Because of the OARE instrument's capability to measure microgravity accelerations, the Office of Space Science and Applications (OSSA) may be interested in using OARE to monitor the microgravity environment during Space Shuttle operation of microgravity experiments. In order to perform this task, it is necessary to process the OARE data near real time. Furthermore, the OARE instrument could be used to monitor the microgravity environment on Space Station.

Space Shuttle Data Flow

Currently, Space Shuttle data is transmitted to the Tracking and Data Relay Satellite System (TDRSS) on three channels, the S-Band, the Ku-Band, and the very high frequency K-Band channel. The S-Band channel is used to transmit mission data and voice on a real time basis during the time when Space Shuttle is in view of either the east satellite or west satellite of the TDRSS. However, for a period of approximately ten minutes of each 90 minute orbit, the Space Shuttle is out-of-view of either TDRSS satellite and no data is transmitted. All mission data are recorded on board the Shuttle for later transmission at a high rate to the TDRSS on the Ku-Band channel. The Ku-Band channel also transmits pre-recorded payload data and real time video data. The K-Band channel is used for special high data rate transmission.

These data bands are transmitted from Space Shuttle via the TDRSS to the NASA ground station near White Sands Missile Range. At the White Sands ground station all the data are re-transmitted over the NASA Communications system (NASCOM) via the Domestic Satellite (DOMSAT) to both a JSC ground station and a NASA Goddard Space Flight Center (GSFC) ground station. The data transmitted to JSC and GSFC are on a C-Band channel in the same format as they were transmitted from the Space Shuttle to TDRSS. Figure 3 shows a diagram of the Space Shuttle data flow . This is a simplified version of the Space Shuttle data flow path presented in the Payload Operations Control Center Capabilities Document (ref. 1). Both the OARE data, which is part of the Space Shuttle payload data and the mission data, are transmitted to JSC and GSFC ground stations. Although the flow paths of the OARE data and the mission data are similar, they are processed and transmitted differently.

OARE Instrument Data Flow

Each of the three orthogonal sensors in OARE takes acceleration data at a sample rate of 20 Hz. The OARE instrument software then averages each sample pair to obtain a data rate of 10 Hz. For normal operation, the 10 Hz data is then filtered to minimize the acceleration signals above 1 Hz. The OARE instrument has onboard data storage and a data buffer that interfaces with the Space Shuttle payload tape recorder as shown in Figure 4. During orbit operations, the buffer dumps data to a continuously running tape recorder approximately every ten minutes at a data rate of 32 Kilobits per second (Kbps). This process takes about 12 seconds to record the most recent ten minutes of data. The data is maintained on the recorder until a command is received to play back the OARE data from the payload recorder via TDRSS. The payload tape recorder data is transmitted on the Ku-Band channel every two to six hours at a data rate of 640 Kbps. Thus each ten minutes of real time data is transmitted to TDRSS and NASCOM for 30 seconds of which 0.6 seconds is data. Four hours of OARE data requires 12 minutes of data transmission time on the Ku-Band and C-Band channels. During reentry, the OARE data is stored on the real time buffer. After landing, the buffer data is dumped to a tape recorder.

As previously mentioned, the OARE data is transmitted through White Sands to the JSC ground station where it is recorded on tape in a PCM format. Currently, there is no "real time" processing of OARE data. After the Space Shuttle flight is completed, the OARE PCM data tape is then converted at JSC to a computer compatible tape in 8 bit bytes which is then mailed to the OARE researchers at LaRC. By this method, preliminary OARE data is provided to LaRC within two days of instrument turn-on and a final tape of the OARE data is provided to LaRC within ten days of the Space Shuttle landing.

Space Shuttle Mission Data Flow

In order for the LaRC researchers to analyze the OARE data, certain mission state parameters are required such as the Shuttle position, translational velocities, angular velocities and accelerations, etc. Table 1 lists the pertinent mission parameters required for analyzing OARE data.

As previously mentioned, the mission data is also transmitted over the C-Band channel to both JSC and GSFC. The mission data is received at JSC where it is recorded and undergoes some processing whereby some data is converted to engineering units. It is then transmitted to GSFC on the NASCOM system in standard NASCOM data blocks at a data rate of 4.8 Kbps on the Calibrated Ancillary System (CAS). The CAS User Accommodation Handbook (ref. 2) describes the details of the CAS system. Because of the amount of CAS data, four (4) data blocks are transmitted simultaneously which results in a CAS data rate of 19.2 Kbps. At GSFC the CAS data is further processed and organized and then distributed to the users including Goddard Space Flight Center (GSFC), Kennedy Space Center (KSC), and Marshall Space Flight Center (MSFC). The NASCOM block format is described in detail in the External Interface Document (ref. 3).

Near Real Time Processing of OARE Data at LaRC

The plan for processing OARE data at LaRC near real time involves three steps: (1) receiving and processing OARE data at LaRC, (2) receiving mission data at LaRC, and (3) performing preliminary analysis of the OARE data and relaying results back to the astronauts.

Proposed OARE Data Flow Process

The OARE data can be received on a near real time basis at LaRC Flight Control Center. The LaRC Flight Control Center currently supports research aircraft flights out of NASA Dryden Flight Research Facility. The data would be received via the NASA Communications (NASCOM) system from DOMSAT at the same time that JSC and GSFC receive the signal on the C-Band channel. Figure 5 shows the OARE data being transmitted to LaRC.

The LaRC Flight Control Center is equipped with a receiver and a deblocker capable of picking the OARE data from the 640 kbps NASCOM stream. A circuit has been designed and fabricated by the Flight Electronics Division (FED) to convert the deblocked OARE data to biphase PCM format for recording. It should be noted that the recorder heads of the LaRC high speed tape recorder are deteriorating and it will cost about $15K to refurbish the recorder. This is recommended if the system is to be operational. Figure 6 shows a block diagram of the proposed LaRC Flight Control System including the Flight Control Center.

The software that will be used to process the OARE data by FED is being developed under another program and will convert the recorded PCM data directly to a digital file for the researchers. The calibration of the acceleration data to counts and engineering units is a complex process that is driven by the on-orbit calibration parameters and the mission parameters, and therefore is part of the analysis procedure performed by the OARE researchers.

Receiving Space Shuttle Mission Data at LaRC

There are two alternatives for obtaining a computer file of pertinent mission data in engineering units near real time at LaRC. The first and simplest is to receive the particular CAS parameters required for analyzing OARE data from one of the CAS users such as KSC, MSFC, or GSFC. One of these users may put all the CAS data or those CAS data parameters required by the OARE researchers (Table 1) on a digital computer file which could be readily networked with computers at LaRC. This would be the short term solution for the demonstration tests. Preliminary conversations with KSC indicate that they have the capability to create a CAS file for LaRC in a NASCOM format data block. This data could be installed on a network computer at KSC and transmitted to LaRC in reasonably short time. It is important to note that KSC currently has a one shift operation to record and transfer CAS data from the NASCOM system. It is, therefore, required that KSC be notified in advance of the times when CAS data is to be recorded during a Space Shuttle Mission.

The other choice is to receive and process CAS data at LaRC. Receiving, recording, and processing of the CAS data will involve some software development to convert the CAS data to engineering units and store on a digital computer file. Although some CAS data parameters have been converted by JSC to engineering units, all data have not been converted. The amount of time and cost to develop this software is minimal and can probably be performed by the OARE researchers. The CAS User Accommodation Handbook (ref. 2) describes the details of the CAS system. Also, if CAS data is to be received at LaRC, it will require an additional deblocker. A deblocker cost is approximately $20K or can be rented for approximately $2K per month which is $4K per Shuttle flight based on a two month requirement. A limited frequency range recorder is available that could record the CAS data that has a rate of 19.2 Kbps. At a cost of $15K, this recorder could be upgraded to receive the 640 Kbps data stream and thus could serve as a backup to the existing OARE data stream recorder. With this backup, LaRC would have operational capability to receive and process the OARE data provided that the mission data be obtained from one of the other CAS customers such as KSC. Figure 7 shows the CAS data flow stream with the two options for receiving the mission data at LaRC.

Demonstration Test Plans

The demonstration test plan to receive, process and analyze OARE data at LaRC on a near real time basis has two options. The first is to transfer mission data as a file to LaRC over a computer data link. The second is to receive and process the CAS data at the LaRC Flight Control Center on a near real time basis.

OARE Data with CAS Data to be Networked to LARC

For the first option that involves only the OARE data, three separate demonstration tests are planned. The first demonstration consists of sending OARE data previously obtained from STS-40 over the NASCOM system from White Sands and receiving, deblocking, and recording the data in PCM format at LaRC. The recorded data can be verified against the STS-40 PCM OARE data tape that currently exists at LaRC. To perform this demonstration test, a test plan needs to be generated for the LaRC Flight Research Monitoring and Control System Group of the Flight Applications Division (FAD), who will be responsible for performing the test. The test involves mailing a tape of the raw OARE STS-40 data to White Sands, requesting clearance from the NASCOM System Manager at GSFC, and coordinating the actual test. It may take several attempts to successfully receive, deblock, and record the data in PCM format at the LaRC Flight Control Center and FED.

The second demonstration test consists of receiving, deblocking, recording, and processing the OARE data in near real time. This test adds the additional step of converting the PCM signal into a digital data file. This test will also involve writing a test plan, setting up the test, and conducting the test in the same manner. However, this test cannot be conducted until the software to convert the PCM stream to a digital file becomes available. That software is presently being developed. The digital data file can be verified with existing STS-40 files.

The third demonstration test involves receiving, processing, and analyzing the OARE data during a Space Shuttle mission. This test assumes LaRC can obtain the pertinent mission data on a digital file from one of the CAS users near real time via a computer network. The requirements for this test are more involved than for the first two demonstrations. In addition to writing a test plan for the LaRC Flight Research Monitoring and Control System Group, a Detailed Test Objective (DTO) must be submitted to the Space Shuttle Flight Integration Manager at JSC. Although it is not necessary to send a tape to White Sands, it is required that the NASCOM System Manager be notified. Also, the pertinent mission data needs to be obtained on a digital file from one of the CAS users near real time. This will require coordination effort with the CAS user. During the actual STS mission there may be travel and per diem costs for a GSFC NASCOM System Operator and some overtime costs for LaRC support contractors. These two costs should be less than $4K for the demonstration test and will be dependent on when the data needs to be received. If it is continuous around the clock, the cost will be greater than if the data only needs to be received during the regular work day. Figure 8 shows a demonstration test schedule for receiving, processing, and analyzing OARE data during a Space Shuttle mission near real time.

OARE Data with CAS Data to be Received Over NASCOM

The second option involves receiving and processing both the OARE and the CAS mission data streams at the LaRC Flight Control Center. This option will require three additional tests making a total of six demonstration tests. The first CAS test will be to receive and record the CAS data, which will require a deblocker and a recorder. A test plan needs to be generated for the LaRC Flight Research Monitoring and Control System Group of FAD, who will be responsible for performing the test. The test involves having the Shuttle/Payload Operations Control Center Interface Facility (SPIF) at GSFC transmit CAS data over the NASCOM system that can be received at the LaRC Flight Control Center. SPIF personnel need to be notified of the specific CAS data parameters that are required by LaRC. Also, clearance needs to be obtained from the NASCOM System Manager at GSFC to use the NASCOM system. It may take several attempts to successfully receive and record the CAS data. To perform this test, only one deblocker and one recorder are required, which may be the same ones used for the OARE data, because the OARE data will not be received during this test.

The second demonstration test for Option 2 will be to receive and process both CAS data and OARE data near real time at LaRC. This test will require the OARE data to be transmitted from White Sands over the NASCOM system to JSC and GSFC and then transmitted to LaRC. The CAS data will be transmitted from JSC to GSFC where it will then be transmitted over the NASCOM system to LaRC during the same time frame. To perform this test, a test plan needs to be generated for the LaRC Flight Research Monitoring and Control System Group, the OARE STS-40 tape needs to be mailed to White Sands, and the NASCOM System Manager at GSFC needs to be notified. Also, a request must be submitted to the SPIF at GSFC defining the mission parameters that are required to be sent to LaRC. To perform this test an additional deblocker is required since both OARE data and CAS data will be simultaneously received at the LaRC Flight Control Center. This deblocker will cost about $2K per month to lease. Also, a second recorder is required, but needs only a limited frequency response to record the CAS data which has a maximum data rate of 19.2 Kbps. Figure 9 shows a demonstration test schedule for receiving and processing the CAS data near real time.

The third Option 2 demonstration test will consist of receiving, processing, and analyzing OARE data and CAS data during a Space Shuttle mission near real time. In addition to the travel, per diem, and overtime costs already defined in the third OARE demonstration test for Option 1, an additional cost of $4K is required to lease a second deblocker for two months prior to and during the Shuttle flight. To perform this test, the DTO would also have to be changed to include the CAS data requirements and a request must be submitted to SPIF at GSFC to have the CAS data transmitted to LaRC.

Demonstration Test Costs

The cost of the demonstration test plan for the first option is nominal if the CAS data is to be obtained on a file from one of the CAS data users such as KSC. For performing the three demonstration tests to receive, process, and analyze the OARE data, the cost will be approximately $4K. This cost is to cover the travel and per diem costs for a GSFC NASCOM system operator to be at LaRC, if required, during the Space Shuttle flight and any overtime costs that are incurred by LaRC support contractors during the Space Shuttle flight. If receiving and processing the OARE data at LaRC is to be operational rather than a demonstration, then the OARE recorder heads should be replaced at a cost of $15K.

For the second option where the CAS data is to be received and processed along with the OARE data, there are additional costs for a deblocker. An additional deblocker is required for a month to perform the third CAS data demonstration test and for two months to perform the Space Shuttle flight demonstration test. The lease cost for the deblocker is $2K per month so that the cost for three months is $6K. Also, there is still the $4K cost for the GSFC NASCOM system operator and the LaRC support contractor overtime during the Space Shuttle flight. The cost to develop the software to convert the CAS data from standard NASCOM block format to engineering units is negligible since this can be performed by the OARE researchers. If the receiving and processing of the OARE and CAS data is to be operational, then it would be wise to purchase an additional deblocker for the LaRC Flight Control Center at a cost of approximately $20K. Secondly, it would cost approximately $15K to upgrade the limited frequency range recorder used for the 19.2 Kbps CAS data so that it could receive the 640 Kbps OARE data. This would allow the recorder to be used as a backup for the OARE data, thus if the OARE recorder fails during a particular Shuttle flight, the CAS data could be obtained on a digital file from another user. The cost for performing the OARE demonstration tests is $4K. The cost for performing both the CAS and the OARE demonstration tests is $10K. The cost for receiving and processing the OARE data on an operational basis is $19K for the first flight and $2K for each succeeding flight since the only costs should be for the LaRC support contractor overtime. The cost for receiving and processing both the CAS and the OARE data on an operational basis is $54K for the first flight and $2K for each succeeding flight since the NASCOM system operator, the CAS recorder upgrade, and the repair of the OARE recorder heads are a one time cost. Figure 10 provides a summary of the costs for the demonstration tests along with the costs for an operation center for receiving and processing both the OARE stream alone and the OARE and CAS data streams simultaneously.

Recommendations

To demonstrate that NASA LaRC can receive and process Space Shuttle data real time, it is deemed important that all pertinent information be received and processed directly without being dependent on others. Therefore, it is recommended that the demonstration test include receiving and processing both the OARE and CAS data streams. Although the $10K cost for this demonstration is greater than the $4K cost of just receiving only the OARE data stream, it would not leave any doubts about the LaRC capability to receive, process, and analyze the Space Shuttle data independently. Although OARE can demonstrate the feasibility, there are other LaRC researchers who have Space Shuttle experiments that require payload and mission data near real time.

References

1. NSTS-21063-POC-CAP, Payload Operations Control Center Capabilities Document, Revision A PCN-1, NASA Johnson Space Center, October 1991.

2. 510-101.28, Calibrated Ancillary System User Accommodation Handbook, Revision 1, NASA Goddard Space Flight Center, April 1991.

3. ICD-E-MCC-009 (JSC-11534, Vol. IX) External Interface Control Document JSC/GSFC CAS Operational Communications ICD for Space Shuttle Missions, NASA Johnson Space Center.

List of Acronyms

CAS	Calibrated Ancillary System
DOMSAT	Domestic Satellite
DTO	Detailed Test Objective
FAD	Flight Applications Division at LaRC
FED	Flight Electronics Division at LaRC
GSFC	NASA Goddard Space Flight Center
JSC	NASA Johnson Space Center
Kpbs	Kilobits per second
KSC	NASA Kennedy Space Center
LaRC	NASA Langley Research Center
MFSC	NASA Marshall Space Flight Center
NASCOM	NASA Communications System
OARE	Orbital Acceleration Research Experiment
OSSA	NASA Office of Space Science Applications
PCM	Pulse Code Modulation
SPIF	Shuttle/Payload Operations Control Center Interface Facility at GSFC
STS	Space Transportation System
TDRSS	Tracking and Data Relay Satellite System

TABLE 1. MISSION DATA REQUIREMENT LIST FOR ANALAYSIS OF OARE DATA

V95H0185C	X comp. of Shuttle pos. vector, M50, ft
V95H0186C	Y comp. of Shuttle pos. vector, M50, ft
V95H0187C	Z comp. of Shuttle pos. vector, M50, ft
V95L0190C	X comp. of Shuttle vel. vector, M50, f/s
V95L0191C	Y comp. of Shuttle vel. vector, M50, f/s
V95L0192C	Z comp. of Shuttle vel. vector, M50, f/s
V90U2240C	M50 to body quaternion ele 1
V90U2241C	M50 to body quaternion ele 2
V90U2242C	M50 to body quaternion ele 3
V90U2243C	M50 to body quaternion ele 4
V90U2641C	M50 WRT LVLH QUAT 1
V90U2642C	M50 WRT LVLH QUAT 2
V90U2643C	M50 WRT LVLH QUAT 3
V90U2644C	M50 WRT LVLH QUAT 4
V95H7473C	Current inertial roll angle, radians
V95H7474C	Current inertial pitch angle, radians
V95H7475C	Current inertial yaw angle, radians
V90H2202C	Body Roll Attitude Euler Angle
V90H2217C	Body Roll Attitude Euler Angle
V90H2230C	Body Roll Attitude Euler Angle
V90H2141C	Body Attitude Error (pitch)
V90H2142C	Body Attitude Error (yaw)
V90H2143C	Body Attitude Error (roll)
V95R7476C	IMU body rate around X-axis, d/s
V95R7477C	IMU body rate around Y-axis, d/s
V95R7487C	IMU body rate around Z-axis, d/s
V90R2223C	IMU derived body rate, X-axis, d/s
V90R2224C	IMU derived body rate, Y-axis, d/s
V90R2225C	IMU derived body rate, Z-axis, d/s
R90H9035C	Shuttle pitch Euler angle, deg
R90H9036C	Shuttle yaw Euler angle, deg
R90H9037C	Shuttle roll Euler angle, deg
V90H2141C	Body Attitude Error (pitch)
V90H2142C	Body Attitude Error (yaw)
V90H2143C	Body Attitude Error (roll)
V90U1961C	Current vehicle mass, slugs

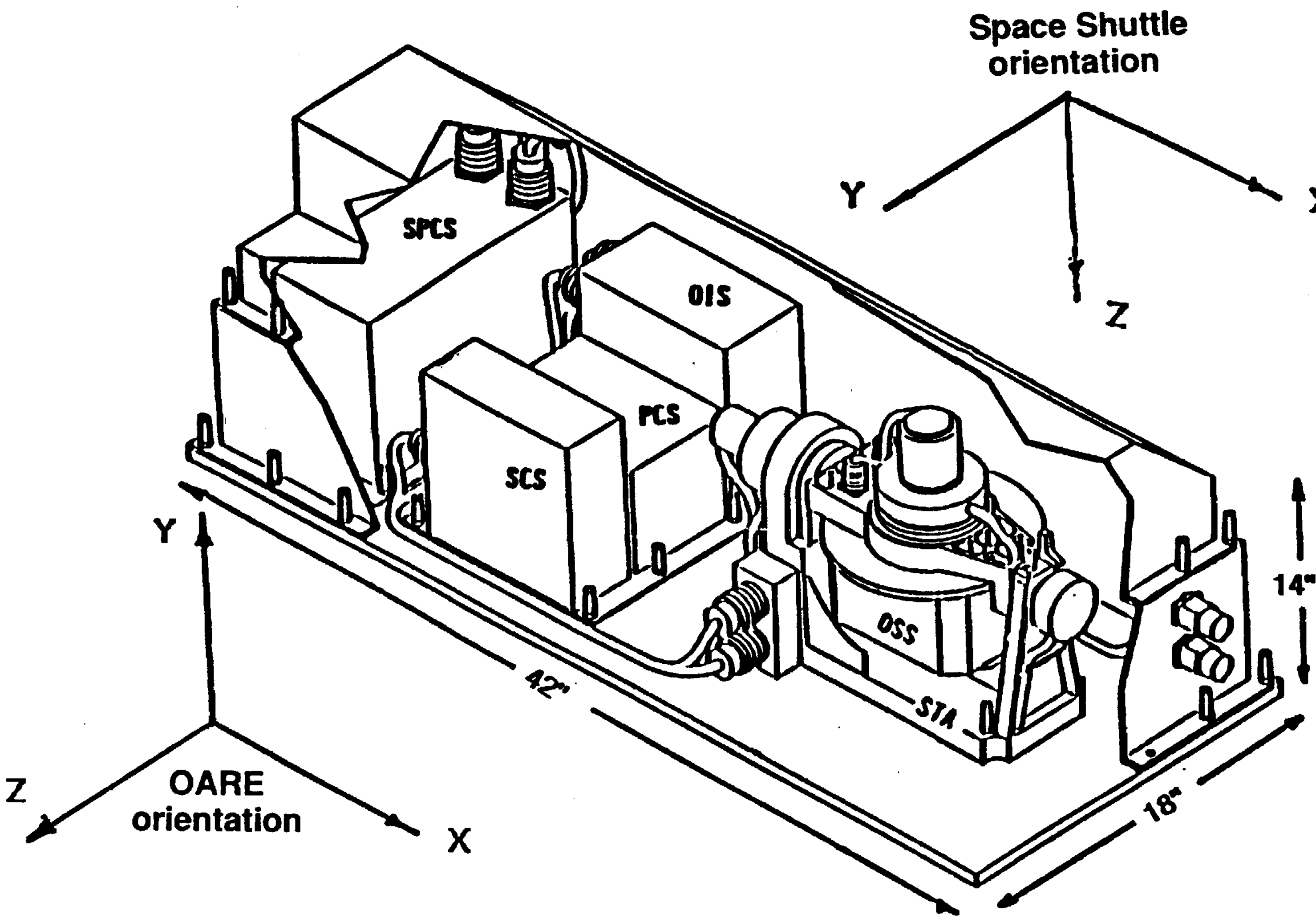


Figure 1. - Orbital Acceleration Research Experiment Package

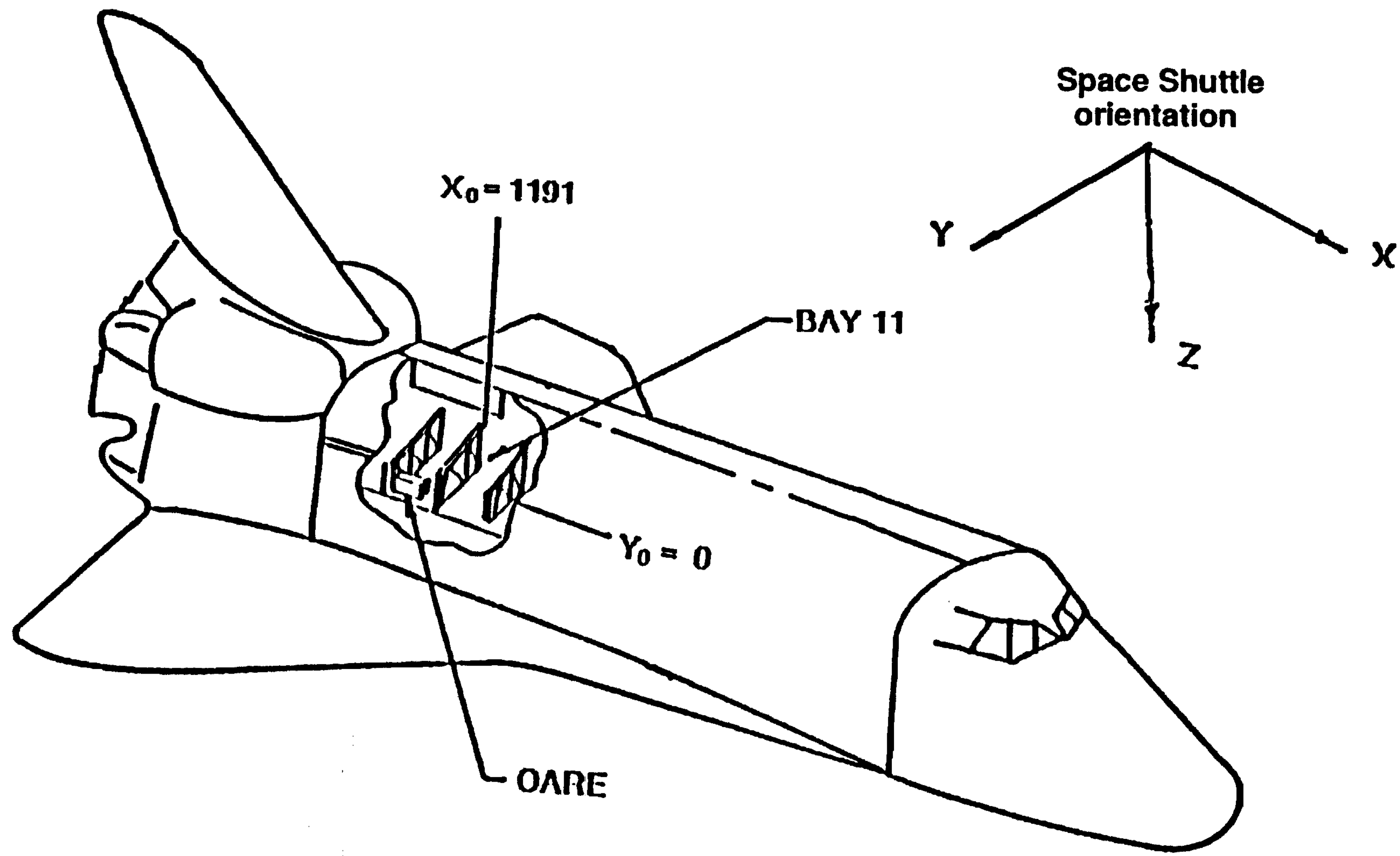


Figure 2. - Installation of Orbital Acceleration Research Experiment

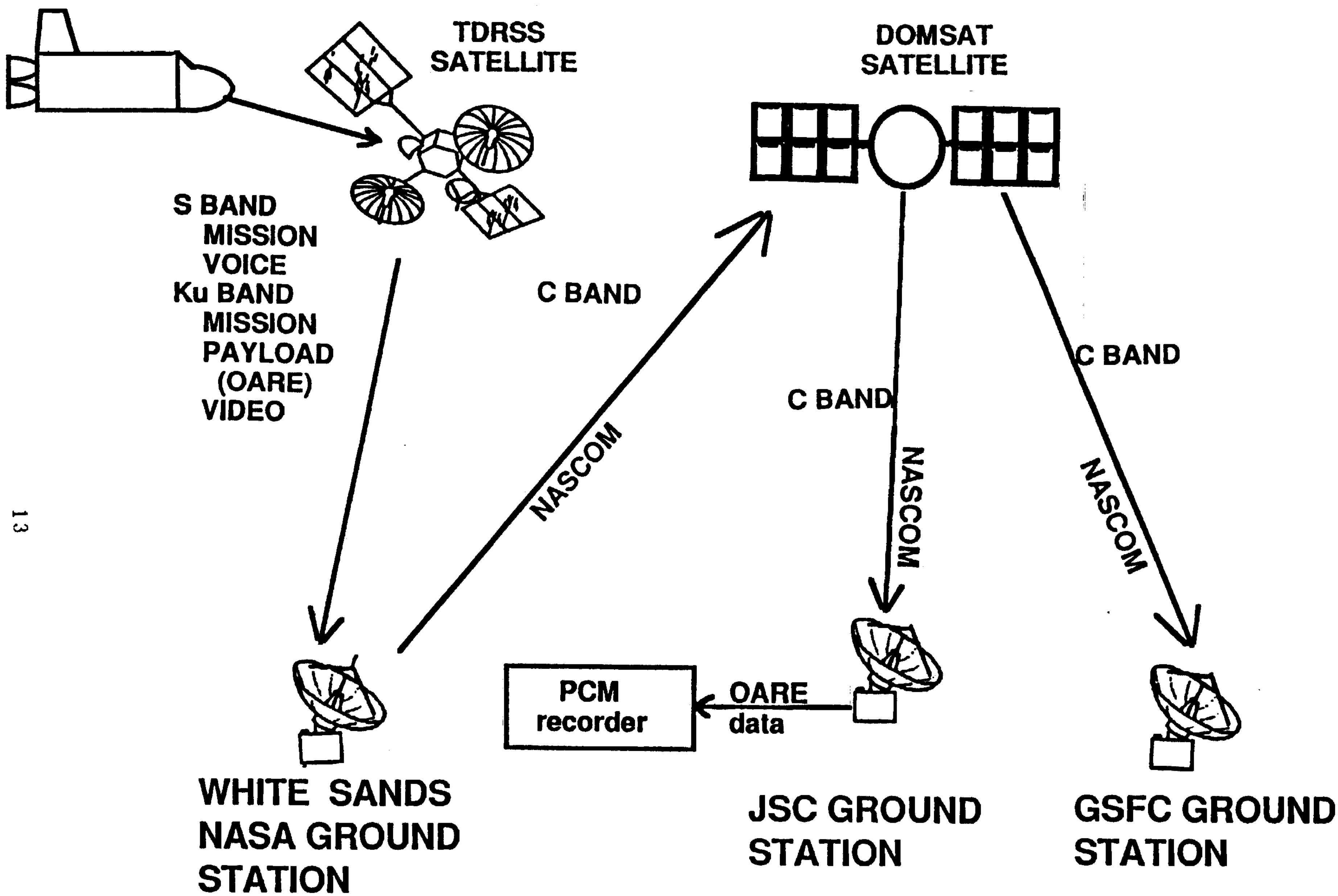


Figure 3. - Space Shuttle Data Flow

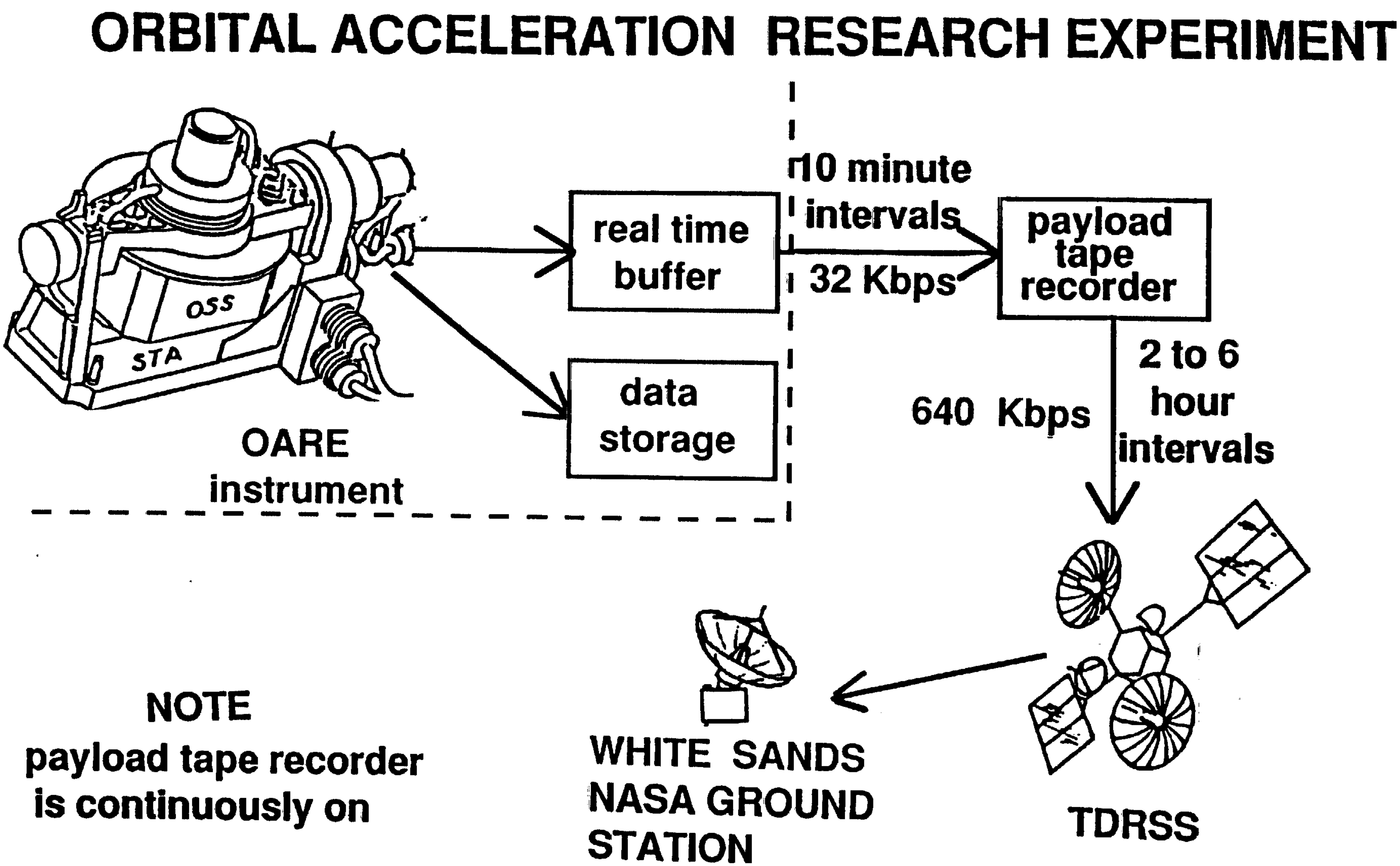


Figure 4. - Orbital Acceleration Research Experiment Data Flow

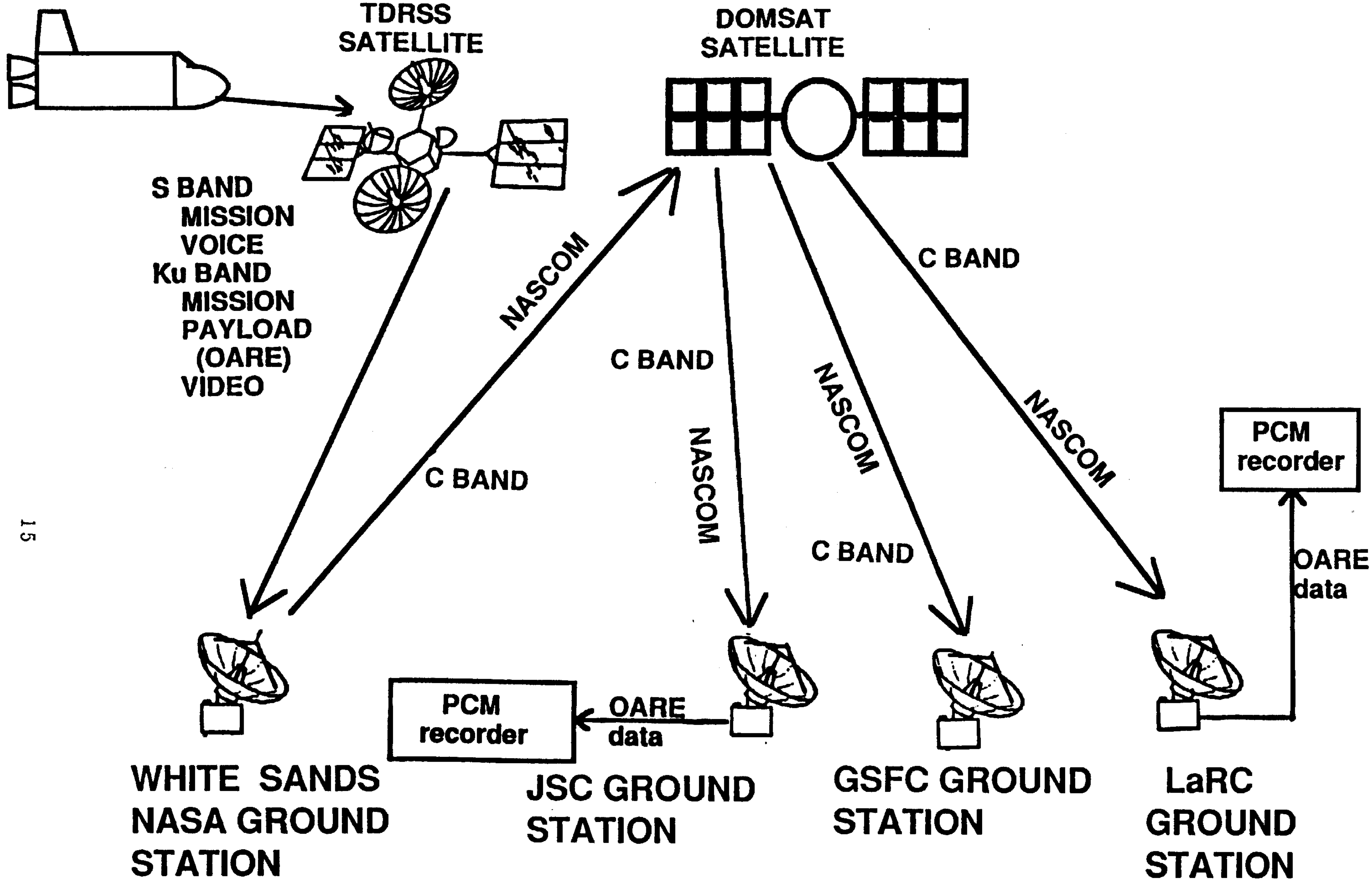


Figure 5. - Space Shuttle Data Flow with Orbital Acceleration Research Experiment Data Transmitted to LaRC

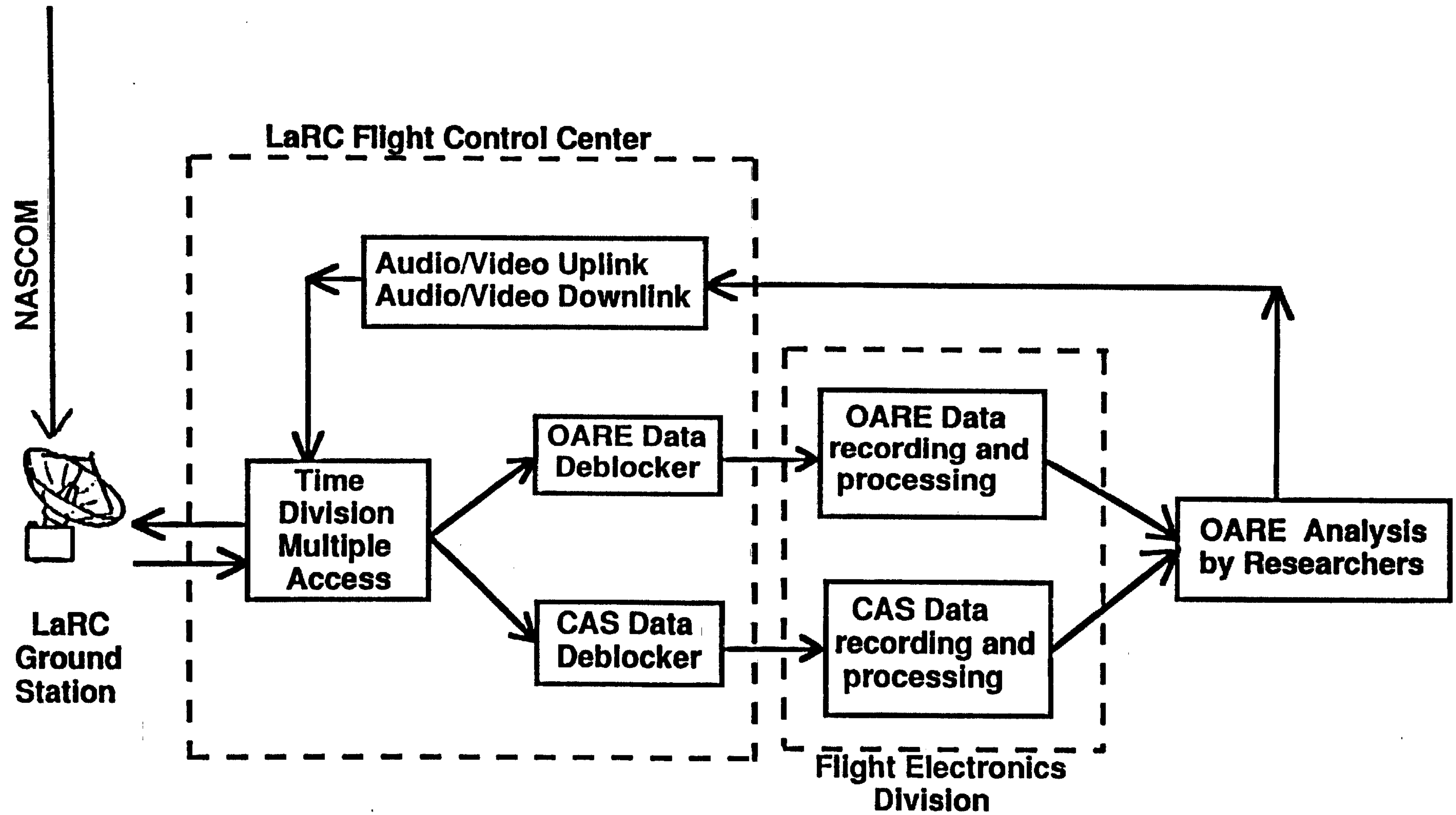
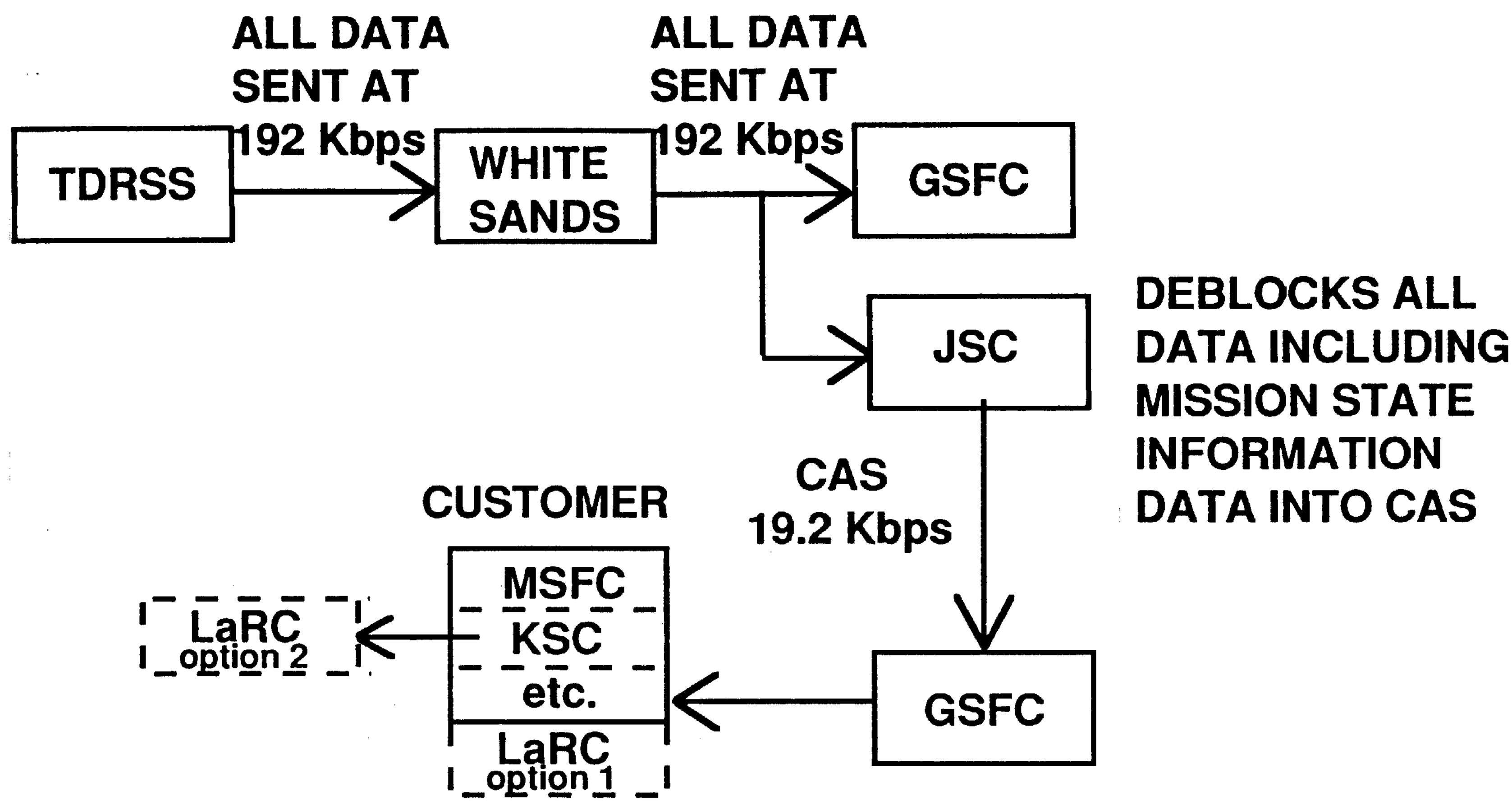


Figure 6. - Proposed LaRC Flight Control System



NOTE: CAS DATA NEEDS TO BE CONVERTED TO ENGINEERING UNITS

Figure 7. - Calibrated Ancillary System Data Flow with 2 Options for Transmitting Data to LaRC

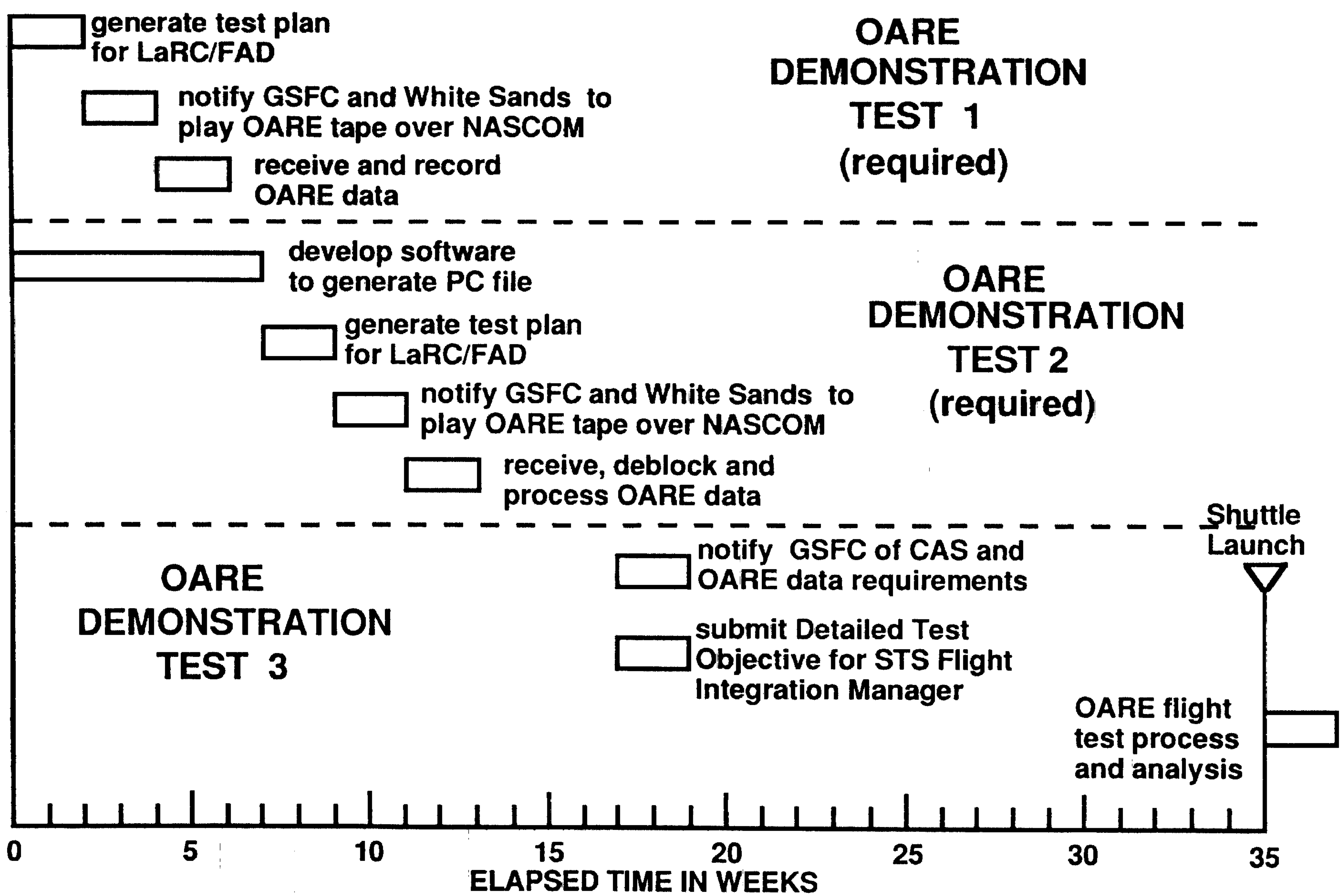


Figure 8. - Option 1 Demonstration Test Schedule for Receiving, Processing, and Analyzing OARE Data at LaRC Near Real Time Assuming Mission Data Supplied by CAS User

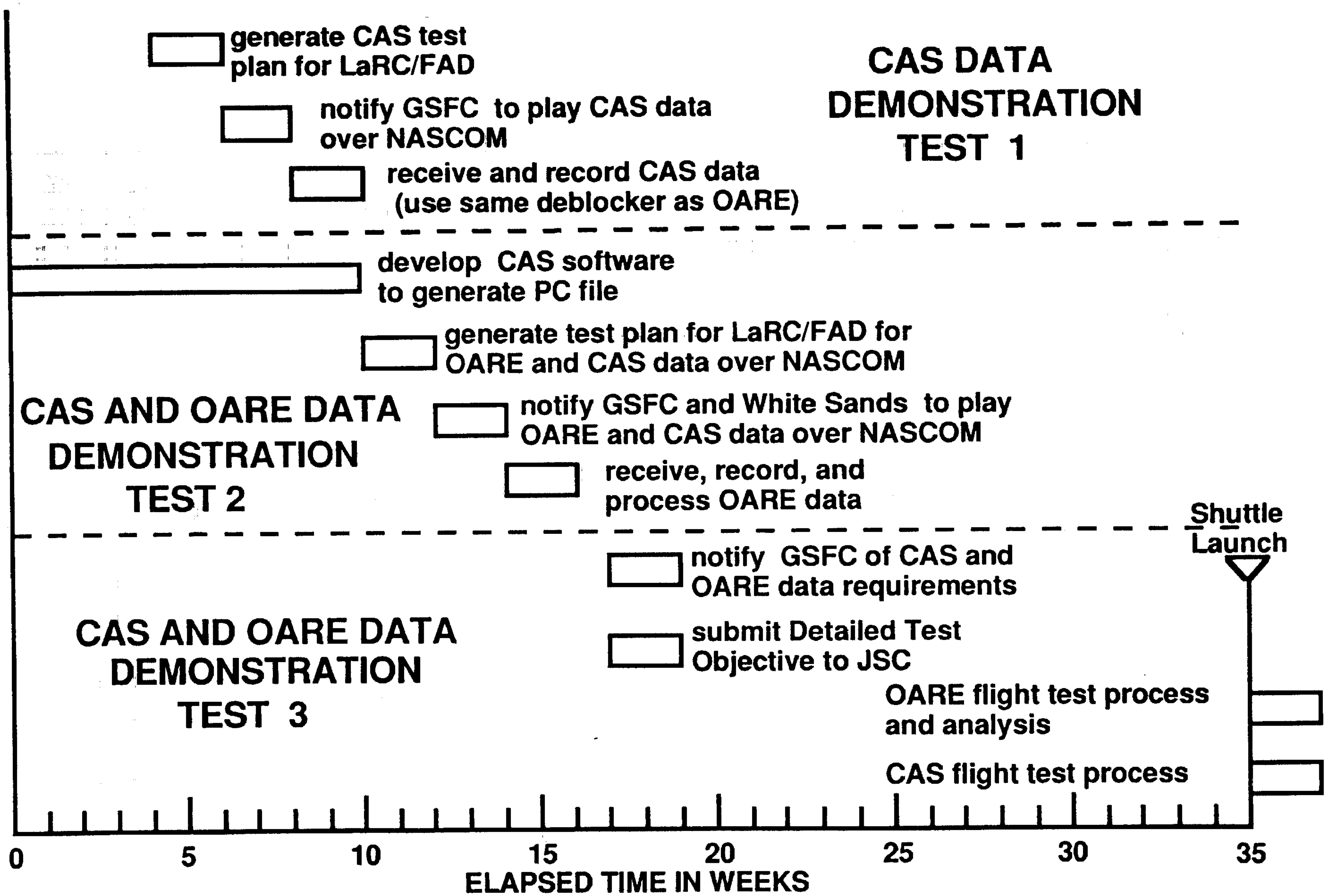


Figure 9. - Option 2 Demonstration Test Schedule for Receiving, Processing, and Analyzing OARE and CAS Data at LaRC Near Real Time

COST ITEM	DEMONSTRATION		OPERATION	
	OARE DATA	OARE + CAS DATA	OARE DATA	OARE + CAS DATA
NASCOM SYSTEM OPER.	2K	2K	2K	2K
OARE RECORDER HEAD REPAIR	—	—	15K	15K
CAS RECORDER UPGRADE	—	—	—	15K
CAS DEBLOCKER	—	6K RENTAL	—	20K PURCHASE
LARC SERVICE CONTRACTOR	2K	2K	2K	2K
FIRST TEST TOTAL COST	4K	10K	19K	54K
COST FOR FOLLOW ON TESTS	NA	NA	2K	2K

Figure 10. - Cost Breakdown for Processing Orbital Acceleration Research Experiment Data Near Real Time

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13. ABSTRACT *(Maximum 200 words)*

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